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Office Note 291

NMC Operational Model Monthly Precipitation Verification December 1981 - November 1983

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Introduction

The monthly precipitation verification program (see Office Note 256, May 1982) used to monitor the quality of NMC's operational model precipitation forecasts was converted from a station to a model gridpoint network system. Instead of interpolating model forecasts to specific observation stations, average observed rainfall amounts are estimated at model gridpoints.

All model gridpoints in the verification area are included. In addition, there is now a consistency between observed and forecast values since they both represent average areal amounts. This makes quantitative precipitation statistics more useful.

The verification system is discussed first. Then, statistics for 12-48 hour forecasts from the operational models--Limited-area Fine-mesh (LFM) and Twelve-layer Spectral (SMG)--are presented for the period, December 1981 to November 1983. Finally, model forecast characteristics are discussed.

Quality of Station Reports

For the record, a summary of station data quality control results from September 1978 to May 1982 is presented in TABLE I. The number of stations monitored (column three) was larger than the actual number used in any verification network.

The percentage of the verification area observed to have measureable precipitation (%R) is presented in column five. The verification network (NET) used to determine %R is also given in this column.

All monitored station reports, for every verification period (two twelve hour periods per day) for each day of the month, were checked. Details of the corrections procedure are given in Office Note 256. The percentage of reports that had to be corrected is shown in column six.

Observations can be lost by the archiving system. The number of verification periods lost is shown in column four. These missing data were recovered manually. If these reports are included as corrections, even though the quality of the station reports is not necessarily involved, the percentage corrected is the value enclosed within parenthesis in column six.

The percentage of station reports corrected is only a small portion of the station data base. However, the percentage corrected is excessive when compared with %R.

The majority of missing reports were found to be dry. If they are discounted, the number of corrections is reduced considerably. In the last column of TABLE I, the percentage of observations with precipitation that had to be corrected is given. At a minimum, more than 20% of the average total precipitation area was affected.

Model Gridpoint Verification Network

The gridpoint networks used in the precipitation verification program are shown in FIGURE I. The LFM grid is drawn as a rectangular array. There are 321 points over the U.S. and portions of southern Canada. Observed area (OBSVD) amount is estimated at each of these gridpoints. Along the borders, adjacent to Canada, Mexico, Pacific and Atlantic Oceans, OBSVD values are determined solely by one or two station reports.

Spectral model gridpoints are not aligned with LFM/OBSVD gridpoints. In FIGURE I, SMG points within the OBSVD network are shown as heavy dots. Observed amounts are interpolated to these SMG locations. Verification points are coincident with forecast gridpoints.

To complete the SMG verification network it is necessary to select OBSVD locations along the borders in close proximity to SMG forecast gridpoints exterior to the OBSVD net. These locations are depicted by circles to indicate that verification and forecast points are not coincident. A forecast amount at the verification point is an interpolated value.

The curvature of the west coast and the alignment of SMG gridpoints made it difficult to select well-spaced verification points. Here, three stations (shown as squares) were added to serve as verification points. Spectral model forecasts are interpolated to these stations rather than to a more distant OBSVD point.

The dotted line in FIGURE I, along the foothills of the Rocky Mountains, divides verification networks into west (WEST) and east (EAST) divisions. All points along the dotted line are considered to be in the west division. There are 106 LFM and 31 SMG verification points over the WEST, 215 LFM and 58 SMG verification points over the EAST.

Verification Procedure

Observed precipitation is estimated subjectively at 321 points in the OBSVD grid network for two 12 hour periods each day of the month. The observed estimate is an average areal amount centered at the gridpoint.

The first step is to determine a 24 hour amount, 12Z the previous day to 12Z of the current day, using the Heavy Precipitation Branch, Forecast Division, analyzed 24 hour observed precipitation chart. The 24 hour map is composed of a plot of station reports and an analysis of one-half inch and succeeding whole inch amounts. River Forecast Center reports (not plotted on this chart) are used in the analysis of heavy precipitation.

Twenty four hour gridpoint estimates are heavily dependent on station reports and contoured areas centered over OBSVD points. The most difficult estimates are for gridpoints within sharp precipitation gradients and near boundaries separating rain/no rain areas. Radar and surface (00Z and 12Z) are used to support precipitation patterns and resolve discrepancies.

The next step is to divide 24 hour observed estimates into two 12 hour (12Z-00Z, 00Z-12Z) totals. Six hourly observed precipitation maps radar and surface charts are used. These six hour observed precipitation charts are composed of only a coarse plot of station reports. Thus, radar summaries, three hour surface and significant weather charts are most useful especially when available station reports misrepresent precipitation patterns depicted on the 24 hour charts. In general, however, 24 and 12 hour estimates of average observed are amounts at gridpoints do not deviate substantially from averaging of observed station amounts. That is, subjective interpretation of the observed precipitation distribution is kept to a minimum.

Partitioning 24 hour totals into two 12 hour amounts can be difficult even when 24 hour rainfall is uniform in coverage and intensity.

This is the result of station distribution with respect to gridpoints as well as variation in both occurrence and intensity of precipitation. In these instances, the 24 hour amount is changed to conform to the two 12 hour totals.

Large contiguous areas of precipitation on 24 hour charts are often the combination of advancing and retreating precipitation events. In these cases, 24 hour amounts often have to be readjusted. For example, in FIGURE II, observed precipitation for two days is presented. For each day, the first 12 hour, second 12 hour and 24 hour station amounts are presented as the top, middle, and bottom figures respectively. The inital approximation of 24 hour gridpoint amounts over portions of North Carolina and Idaho, using the 24 hour chart exclusively, would be larger than the estimate derived from the two 12 hour charts. Here, the 24 hour total is changed in favor of the 12 hour amounts.

Even though a reasonable representation of observed precipitation for the gridpoint network is attained by careful consideration of observed precipitation maps along with other charts, it is not always possible to reproduce the observed field from gridpoint estimates. For example, in FIGURE III, 24 hour contoured observed charts for two days in January 1982 are shown. The LFM/OBSVD network is indicated by grid arrangement and SMG points by crosses. Heavy precipitation areas are large and alinged with OBSVD network points. However, there are regions, .50" over NE Louisiana plus the small 1" areas in the top figure and the .50" area over South Alabama in the bottom figure that are to small for the OBSVD net.

The OBSVD network is able to depict alternating wet and dry areas for these January cases. Spectral points, however, would show southwestern Arkansas (top figure) as wet and all of southeastern Mississippi (bottom figure) as dry.

During summer, locally heavy precipitation cannot be represented by the OBSVD net. Location as well as scale of precipitation events are important during warm months. An example is presented in FIGURE IV (August 1983).

Observed precipitation used to verify LFM and SMG forecasts represents only that portion of the observed field that the models, because of gridpoint alignment and resolution, should be expected to predict. Evaluation for anything more is unrealistic.

Verification Statistics

For each verification network (or division), composed of N gridpoints, the total number of gridpoints forecast (F) compared to the number observed to have measurable precipitation (O) yield the number of correctly forecast points, hits (H). Precipitation verification statistics are:

Precipitation Threat Score:	$TSP = H / (F + O - H)$	(1)
No-Precipitation Threat Score:	$TSNP = [N - (F + O - H)] / (N - H)$	(2)
Bias:	$BIAS = F / O$	(3)

Both TSP and BIAS vary considerably with the occurrence of precipitation. To assist in the interpretation of TSP and BIAS fluctuations, the percentage of the verification network observed to have measureable precipitation, %R (also %RAIN), is calculated.

Percentage Rainfall Coverage:	$\%R = O / N$	(4)

For quantitative precipitation (QP) evaluation, gridpoints with observed and forecast amounts exceeding critical threshold values (.25", .50", etc) are tabulated. Hits are determined. Precipitation threat score and bias are found using equations (1) and (3) respectively. A no-quantitative precipitation threat score, TSNQ, is calculated using equation (2). Here, N is not the total number of gridpoints in the network, but the area defined by F and O. That is,

$N = F_{\geq .01} + O_{\geq .01} - H_{\geq .01}$ for .25" threshold

$N = F_{>.25} + O_{>.25} - H_{>.25}$ for .50" threshold

Percentage observed QP (%QP) is defined by:

$\%QP = O_{>.25} / O_{>.01}$ for .25" threshold

$\%QP = O_{>.50} / O_{>.25}$ for .50" threshold

All verification statistics presneted in tables and figures have been scaled by 100.

Station Versus Gridpoint Networks

A comparison of observed precipitation estimates using station and gridpoint networks was done for winter 1982. The fine-mesh 190 station verification network (see Office Note 256), 62 station over theWEST and 128 stations over the EAST, was used. In FIGURE V, station (○) and gridpoint (●) values for each month are presented for WEST (left half) and EAST (right half) divisions. On the bottom, %RAIN distribution is shown while the remainder of each graph depicts the percentage of the precipitation area (%QUANT) occupied by critical threshold amounts.

Station networks underestimate average areal coverage of measureable precipitation and overestimate the distribution of critical QP amounts. Also, monthly variation is inadequately represented. These deficiencies are due to station network resolution and the use of single statin reports to represent areal coverage, especially of heavy precipitation. Observed precipitation estimates during warm months would suffer even more by comparison with gridpoint estimates.

Verification statistics for winter 1982 are presented in TABLE II. Station network values are enclosed within parentheses. Differences in station and gridpoint estimates of observed precipitation distribution are evident in these numbers. For example, gridpoint biases for categorical (rain/no rain) forecasts are smaller whereas for QP forecasts (especially over the EAST) they are slightly larger. Complete coverage of the verification area by the gridpoint network results in a bit larger TSP.

Charcteristics of Model Precipitation Forecasts

This section summarizes monthly statistics from December 1981 to November 1983. Numerical models in operation during the evaluation period were:

1. Fine-mesh (53 x 57 point, 190.5KM true at 60 N) Fourth Order LFM
2. Coarse-mesh (65 x 65 point, 381KM true at 60 N) Twelve layer SMG, 30 waves thru October 1983, 40 waves subsequently

During August 1982, precipitation parameterization methods used in both the LFM and SMG were modified. Also, both models were converted to run on a new computer, the CYBER, last autumn.

Precipitation verification statistics for the LFM and SMG categorical (rain/no rain) forecasts are presented in TABLES IIIa and IIIb. Statistics, TSP, BIAS, and %RAIN, are shown by months for both EAST and WEST divisions. The number of forecasts available is also indicated. These monthly statistics are tabulated by seasons in TABLE IV. No-precipitation threat score is also included in this table.

Precipitation forecast characteristics can best be illustrated by plotting some of the data in the seasonal summary (TABLE IV). In FIGURE VIa (LFM) and FIGURE VIb (SMG), 12 and 48 hour TSP and BIAS are plotted. Twelve hour values (o) are connected by solid lines and 48 hour values (•) by dashed lines. If neither of these TSPs is the maximum value for the 12 thru 48 hour forecast cycle, the maximum is plotted with an X. Columns are used for seasonal %Rain distribution. The WEST division is on the left half and EAST division on the right half of the figure. Summer of 1982 is indicated by a thin vertical line to separate the record into before and after periods when precipitation parameterization methods were modified.

Twelve hour LFM biases are substantially less than those observed before summer 1982. Overall, biases increase with time becoming very wet over the

WEST and relatively wet over the EAST at 48 hours. An exception to this trend occurs during summer over the EAST when biases are largest at 12 hours and decrease with time. LFM TSP's are smallest during summer months. Threat scores increase during cooler seasons and are positively correlated with %RAIN conditions.

The SMG (FIGURE VIb) is very dry during summer. During other seasons biases start out rather dry and increase with time. Wet values are found at 48 hours over the WEST. A small increase in SMG biases for all forecast hours was observed after summer 1982. Also, the 40 mode SMG appears to have slightly larger biases at 12 and 24 hours (see TABLES IIIa and IIIb).

Spectral model TSP's are minimal during summer. For other seasons, dry 12 hour biases shift TSP maxima to 24 and even 36 hours. Threat score and %RAIN are positively correlated.

Quantitative precipitation verification statistics for .25" and .50" threshold amounts are presented in TABLE Va (LFM) and TABLE Vb (SMG). Seasonal statistics for both EAST and WEST divisions include: TSP, BIAS, TSNQ, and %QP.

Twelve hour LFM QP biases are much smaller after summer 1982. Increasing bias with time trend plus the exception noted earlier for categorical (rain/no rain) forecasts is also characteristic of QP forecst over the WEST. Over the EAST, summer and autumn are relatively dry. In winter and spring, QP biases grow rapidly during the first 24 hours and are steady or slightly decreasing during the last 24 hours.

Spectral model QP biases are much drier after summer of 1982. Overall, biases grow with time but summer months remain extremely dry.

TABLE I

YEAR	MONTH	STATIONS MONITORED	# OF 12HR PRDS MSG	%R/NET	% OF STNS CORRECTED (INCLDG MSG PRDS)	% OF STNS CORRECTED AFTR ZEROING MSG RPTS
1978	SEP	261	2	17/ 90	11.9 (14.9)	
	OCT	261	3	10/ 90	10.5 (14.8)	
	NOV	261	3	23/ 90	9.4 (14.2)	
1979	FEB	261	7	25/ 90	9.9 (21.2)	
	MAR	261	6	21/ 90	18.6 (26.4)	
	APR	261	3	22/ 90	9.5 (14.0)	
	MAY	157	15	21/ 90	13.4 (34.4)	
	JUN	157	12	14/ 90	10.4 (28.3)	
	JUL	157	0	16/ 90	12.8 (12.8)	
	AUG	196	3	18/190	14.0 (18.2)	
	SEP	196	3	13/190	13.4 (17.7)	
	OCT	196	14	14/190	9.4 (29.9)	
	NOV	196	8	16/190	10.7 (22.6)	
	DEC	196	4	14/190	8.2 (14.2)	
1980	JAN	196	6	21/190	14.1 (22.4)	
	FEB	196	0	18/190	10.1 (10.1)	
	MAR	196	54	22/190	* *	
	APR	196	1	16/190	10.9 (12.4)	
	MAY	196	2	19/190	10.9 (13.8)	
	JUN	196	2	14/190	10.4 (13.4)	
	JUL	196	3	13/190	11.5 (15.8)	
	AUG	196	0	15/190	11.2 (11.2)	
	SEP	196	6	16/190	12.0 (20.8)	
	OCT	196	2	13/190	10.1 (13.7)	
	NOV	196	0	15/190	15.7 (15.7)	
	DEC	196	2	15/190	15.1 (17.8)	
1981	JAN	196	2	12/190	15.0 (17.7)	
	FEB	196	2	18/190	16.1 (19.1)	
	MAR	196	2	17/190	15.6 (18.3)	
	APR	196	16	16/190	16.2 (38.5)	
	MAY	196	8	21/190	17.4 (28.1)	
	JUN	196	10	18/190	20.0 (33.3)	
	JUL	196	4	17/190		5.6
	AUG	196	4	16/190		5.1
	SEP	196	0	14/190		4.7
	OCT	196	3	19/190		6.2
	NOV	196	2	15/190		6.1
	DEC	196	0	20/190		6.3
1982	JAN	196	4	22/190		7.7
	FEB	196	0	19/190		5.1
	MAR	102	0	23/101		5.4
	APR	102	0	18/101		6.0
	MAY	102	0	18/101		8.3

TABLE II

PRECIPITATION VERIFICATION: LFM, Winter 1982
Gridpoint Network: EAST215, WEST106
(Station Network): EAST128, WEST62

THRESHOLD	≥ .01"	> .25"	> .50"
EAST......			
TSP--12HR	50 (47)	41 (40)	31 (30)
24HR	49 (46)	40 (37)	29 (26)
36HR	44 (42)	35 (34)	27 (26)
48HR	38 (37)	27 (26)	18 (17)
BIAS-12HR	113 (123)	132 (128)	120 (114)
24HR	132 (142)	133 (131)	125 (116)
36HR	134 (143)	143 (141)	143 (137)
48HR	132 (144)	140 (140)	137 (134)
WEST......			
TSP--12HR	45 (41)	33 (31)	33 (25)
24HR	40 (37)	25 (24)	23 (21)
36HR	37 (33)	20 (19)	17 (15)
48HR	34 (31)	17 (16)	13 (12)
BIAS-12HR	192 (207)	179 (177)	118 (137)
24HR	222 (242)	235 (227)	160 (168)
36HR	235 (254)	261 (254)	195 (220)
48HR	244 (268)	291 (290)	283 (307)

TABLE IIIa

PRECIPITATION VERIFICATION: LFM, SMG
Gridpoint Network: LFM ... EAST215, WEST106
SMG ... EAST58, WEST31
** ... Precipitation parameterization in both models were modified

LFM	DEC81	JAN82	FEB82	MAR82	APR82	MAY82	JUN82	JUL82	AUG82 **	SEP82	OCT82	NOV82
#FCSTS	62	59	51-56	62	60	62	60	62	58	58	60	60
EAST......												
TSP--12HR	49	51	49	48	50	49	42	35	34	40	46	51
24HR	49	51	46	45	49	51	41	38	36	40	44	51
36HR	45	45	43	41	46	48	40	35	34	37	41	45
48HR	37	41	35	37	41	45	35	32	31	35	36	40
BIAS-12HR	113	109	120	141	141	166	183	218	162	140	115	101
24HR	128	131	139	157	146	135	147	157	151	141	136	130
36HR	125	137	140	168	141	125	127	123	136	141	147	133
48HR	119	139	139	164	135	128	126	111	133	144	156	137
%RAIN	20.8	26.5	20.7	22.4	22.9	30.4	27.0	25.6	22.4	20.2	18.5	22.4
WEST......												
TSP--12HR	48	44	42	46	44	34	34	32	23	42	47	50
24HR	44	40	37	43	37	32	33	28	23	39	42	46
36HR	40	37	33	41	34	29	32	28	21	35	37	43
48HR	35	35	30	38	32	28	28	25	21	31	32	39
BIAS-12HR	179	200	197	195	191	211	198	194	163	155	125	145
24HR	210	232	223	210	234	217	179	183	164	174	188	188
36HR	219	247	237	220	256	230	174	177	167	183	214	206
48HR	232	252	249	219	265	228	173	179	177	189	226	212
%RAIN	21.2	23.8	18.6	24.9	14.9	13.0	13.9	14.3	14.3	20.7	13.6	20.4

SMG	DEC81	JAN82	FEB82	MAR82	APR82	MAY82	JUN82	JUL82	AUG82 **	SEP82	OCT82	NOV82
#FCSTS	62	59-60	55-56	62	60	62	59	60-61	55	58	60	59
EAST......												
TSP--12HR	33	40	35	32	30	14	15	7	17	25	29	39
24HR	37	41	33	35	34	19	19	7	15	27	32	43
36HR	34	38	32	32	33	21	16	6	14	24	31	38
48HR	30	37	27	30	30	19	14	5	14	22	29	37
BIAS-12HR	52	70	51	49	44	17	21	12	40	54	54	69
24HR	84	106	78	74	66	29	31	14	42	64	60	102
36HR	98	115	90	87	83	37	36	12	34	62	67	103
48HR	97	111	95	100	81	36	39	11	33	64	71	110
%RAIN	19.4	24.2	19.9	21.2	21.7	29.6	25.7	25.1	22.7	20.6	17.9	21.3
WEST......												
TSP--12HR	46	42	39	34	40	12	5	4	1	21	30	40
24HR	52	49	48	44	47	16	7	4	6	32	41	48
36HR	50	47	43	44	43	18	8	6	6	34	40	48
48HR	41	42	45	43	40	15	13	7	5	27	36	44
BIAS-12HR	67	70	62	53	58	17	6	5	4	32	62	74
24HR	100	118	95	95	104	37	17	6	13	62	112	120
36HR	113	132	116	122	131	58	24	14	17	78	131	141
48HR	121	142	135	132	156	86	34	22	20	79	149	153
%RAIN	23.2	27.1	19.9	26.6	16.0	11.7	12.8	14.0	12.9	20.4	15.1	22.9

TABLE III b

PRECIPITATION VERIFICATION: LFM, SMG
Gridpoint Network: LFM ... EAST215, WEST106
SMG ... EAST58, WEST31
* ... Forty-wave SMG

LFM	DEC82	JAN83	FEB83	MAR83	APR83	MAY83	JUN83	JUL83	AUG83	SEP83	OCT83	NOV83
#FCSTS	61-62	61-62	55	62	58	61	50-52	62	59-60	58	59-60	60
EAST......												
TSP--12HR	52	49	54	57	58	50	43	30	30	40	49	58
24HR	50	47	48	52	55	47	43	30	31	40	47	55
36HR	44	44	41	46	50	44	39	29	29	36	43	49
48HR	39	38	36	41	44	39	36	25	26	32	37	43
BIAS-12HR	97	91	96	112	113	126	125	140	163	137	117	114
24HR	127	125	127	139	135	137	136	128	148	148	129	136
36HR	139	129	144	152	141	141	130	121	131	139	129	141
48HR	149	135	151	164	139	144	131	110	129	137	130	145
%RAIN	24.5	18.3	18.6	24.0	24.4	25.7	24.8	17.5	18.6	18.6	19.3	22.7
WEST......												
TSP--12HR	54	48	51	52	43	41	33	28	29	33	38	51
24HR	47	42	48	49	39	37	33	31	32	32	35	44
36HR	41	38	42	46	35	33	30	32	29	27	30	40
48HR	37	34	38	44	34	29	25	27	29	24	27	38
BIAS-12HR	137	134	136	145	157	154	151	175	180	198	171	150
24HR	182	188	177	180	193	192	187	184	178	219	207	203
36HR	205	209	185	186	226	193	213	199	205	248	240	214
48HR	218	223	199	184	234	202	215	206	202	265	260	218
%RAIN	22.4	20.5	26.4	32.6	19.6	13.8	15.2	15.1	18.7	14.5	12.5	26.9

SMG	DEC82	JAN83	FEB83	MAR83	APR83	MAY83	JUN83	JUL83	AUG83	SEP83	OCT83	NOV83 *
#FCSTS	62	62	56	62	59	61	50-53	62	54-59	51	38-42	55-56
EAST......												
TSP--12HR	39	36	44	45	47	33	24	15	15	22	29	47
24HR	45	43	43	48	46	35	25	14	14	25	34	50
36HR	42	40	40	42	44	34	21	12	12	19	33	47
48HR	37	34	35	40	40	30	22	9	10	20	25	39
BIAS-12HR	66	62	79	79	77	66	49	41	44	58	56	82
24HR	96	107	111	109	96	82	55	37	38	63	71	94
36HR	112	120	121	128	104	92	54	28	31	54	75	100
48HR	126	116	126	133	112	97	55	25	24	58	71	93
%RAIN	22.7	17.8	18.5	23.2	23.1	23.7	24.0	17.9	18.3	19.1	21.3	21.8
WEST......												
TSP--12HR	50	44	43	43	30	25	14	12	3	12	25	52
24HR	48	46	48	49	36	36	22	21	8	17	29	52
36HR	44	44	45	48	32	38	23	20	8	17	30	49
48HR	42	39	47	46	31	32	23	21	9	14	29	44
BIAS-12HR	90	95	81	76	50	35	22	18	5	15	45	84
24HR	149	147	134	129	103	73	48	34	11	36	90	130
36HR	164	168	153	150	142	92	66	44	11	56	121	140
48HR	171	196	169	159	168	99	81	60	20	90	160	152
%RAIN	23.3	21.7	28.8	34.0	21.2	14.5	14.9	15.2	16.5	12.4	12.6	29.1

TABLE IV

PRECIPITATION VERIFICATION: LFM
Gridpoint Network: EAST215, WEST106

	WIN82	SPR82	SUM82	AUT82	WIN83	SPR83	SUM83	AUT83
#FCSTS	173–177	184	180	178	178	181	171–174	177–178
EAST......								
TSP--12HR	50	49	37	45	52	55	34	49
24HR	49	48	38	45	48	51	35	48
36HR	44	45	36	41	43	46	33	43
48HR	38	41	33	37	38	41	29	38
BIAS-12HR	113	151	189	118	95	117	142	122
24HR	132	145	152	136	126	137	137	137
36HR	134	143	128	140	137	145	128	137
48HR	132	141	123	145	145	149	124	138
TSNP-12HR	80	72	59	81	85	80	73	82
24HR	78	73	66	79	81	76	74	80
36HR	76	71	68	76	77	73	74	78
48HR	73	69	67	74	74	69	73	75
%RAIN	22.7	25.2	25.0	20.4	20.5	24.8	20.0	20.2
WEST......								
TSP--12HR	45	42	30	46	51	47	30	42
24HR	40	39	28	43	45	43	32	39
36HR	37	36	27	38	40	40	30	34
48HR	34	34	24	34	36	37	27	31
BIAS-12HR	192	198	185	144	136	151	170	168
24HR	222	219	176	183	182	186	182	208
36HR	235	232	172	199	199	198	205	229
48HR	244	234	176	207	213	202	207	240
TSNP-12HR	70	75	76	81	79	75	74	77
24HR	64	71	76	75	77	69	73	71
36HR	59	67	76	71	64	65	70	65
48HR	55	66	74	68	58	62	67	63
%RAIN	21.3	17.6	14.2	18.2	23.0	22.1	16.4	18.0

PRECIPITATION VERIFICATION: SMG
Gridpoint Network: EAST58, WEST31

	WIN82	SPR82	SUM82	AUT82	WIN83	SPR83	SUM83	AUT83
#FCSTS	177	184	174–175	177	180	182	166–174	144–148
EAST......								
TSP--12HR	36	24	13	32	40	41	18	34
24HR	38	29	13	34	44	43	18	37
36HR	35	28	12	31	41	40	15	34
48HR	32	26	11	30	35	37	14	29
BIAS-12HR	58	34	24	59	69	74	45	67
24HR	91	53	28	76	104	96	44	77
36HR	102	65	27	78	117	108	39	78
48HR	102	68	27	83	123	114	36	76
TSNP-12HR	83	79	76	82	84	81	79	81
24HR	79	78	75	81	82	79	79	82
36HR	77	76	75	80	79	76	79	80
48HR	75	74	74	79	76	73	79	78
%RAIN	21.2	24.2	24.5	19.9	19.7	23.3	19.9	20.7
WEST......								
TSP--12HR	43	31	4	31	46	36	10	39
24HR	50	39	6	41	47	43	17	41
36HR	47	39	7	41	44	41	17	39
48HR	43	36	8	37	43	38	18	34
BIAS-12HR	67	47	5	56	88	60	14	61
24HR	105	85	11	98	143	110	30	101
36HR	121	111	19	117	161	135	39	117
48HR	133	129	25	127	178	149	53	140
TSNP-12HR	82	85	87	83	80	80	85	85
24HR	81	84	87	82	74	77	85	82
36HR	78	81	86	80	69	73	84	80
48HR	74	78	86	77	66	69	83	76
%RAIN	23.4	18.1	13.3	19.4	24.4	23.3	15.5	18.8

TABLE V a

QUANTITATIVE PRECIPITATION VERIFICATION: LFM
Gridpoint Network: EAST215, WEST106

	WIN82	SPR82	SUM82	AUT82	WIN83	SPR83	SUM83	AUT83
#FCSTS	173-177	184	180	178	178	181	171-174	177-178

.25" Threshold

	WIN82	SPR82	SUM82	AUT82	WIN83	SPR83	SUM83	AUT83
EAST......								
TSP--12HR	41	30	20	28	43	36	15	37
24HR	40	27	17	29	36	36	15	34
36HR	35	24	13	24	30	29	12	29
48HR	27	19	11	21	26	22	11	22
BIAS-12HR	132	146	164	73	91	93	64	81
24HR	133	119	69	92	137	133	69	108
36HR	143	136	52	100	145	142	70	105
48HR	140	138	49	98	146	129	63	93
TSNQ-12HR	86	79	72	80	85	78	81	81
24HR	87	80	79	80	81	76	69	79
36HR	85	77	77	78	79	73	78	78
48HR	84	75	77	78	79	73	79	77
%QP	18.9	24.8	31.4	29.0	23.4	30.1	27.1	29.9
WEST......								
TSP--12HR	33	21	6	24	30	21	5	21
24HR	25	17	5	22	26	21	8	21
36HR	20	15	3	17	20	17	4	16
48HR	17	11	3	14	17	16	7	16
BIAS-12HR	179	195	256	107	125	85	142	137
24HR	235	267	114	176	217	179	142	230
36HR	261	287	117	179	224	185	133	220
48HR	291	233	114	162	265	224	119	222
TSNQ-12HR	88	90	90	86	83	90	91	86
24HR	84	88	94	84	79	87	91	84
36HR	82	88	94	84	78	86	92	84
48HR	80	89	94	85	76	85	93	85
%QP	17.0	10.2	6.8	17.3	20.2	14.0	8.9	16.1

.50" Threshold

	WIN82	SPR82	SUM82	AUT82	WIN83	SPR83	SUM83	AUT83
EAST......								
TSP--12HR	31	22	13	22	34	28	11	25
24HR	29	19	8	19	28	28	9	24
36HR	27	16	7	16	24	19	6	19
48HR	18	11	5	14	18	14	5	13
BIAS-12HR	120	119	144	56	94	84	34	67
24HR	125	108	38	80	146	144	54	104
36HR	143	135	30	91	151	154	51	100
48HR	137	140	32	87	144	129	47	80
TSNQ-12HR	60	65	58	58	54	57	65	57
24HR	58	62	62	54	50	52	60	54
36HR	57	59	61	52	50	49	60	53
48HR	55	57	58	53	49	50	59	53
%QP	48.0	42.6	45.5	50.8	52.5	50.1	44.0	49.6
WEST......								
TSP--12HR	33	19	2	17	27	17	3	17
24HR	23	13	0	17	20	15	4	16
36HR	17	14	2	11	16	14	3	11
48HR	13	13	0	8	14	12	5	13
BIAS-12HR	118	154	285	86	102	67	149	125
24HR	160	189	109	122	187	156	116	212
36HR	195	190	103	137	208	170	64	189
48HR	283	139	73	117	256	263	60	251
TSNQ-12HR	73	77	80	71	67	73	74	70
24HR	70	77	82	74	64	72	77	70
36HR	66	79	83	71	61	71	82	70
48HR	58	80	85	71	60	64	81	65
%QP	45.2	31.1	17.8	35.1	43.8	33.1	25.8	34.4

TABLE V b

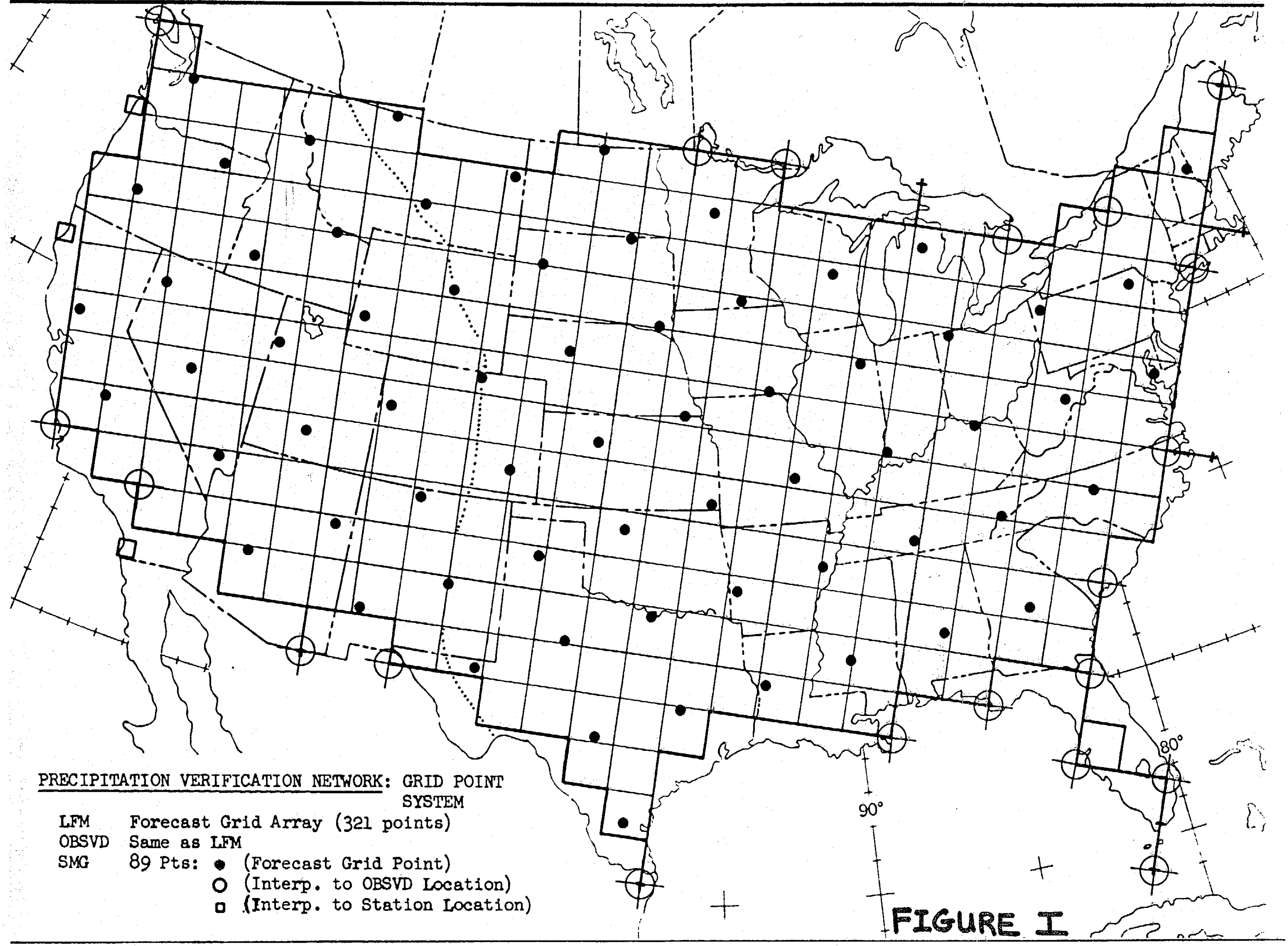
QUANTITATIVE PRECIPITATION VERIFICATION: SMG
Gridpoint Network: EAST58, WEST31

.25" Threshold

	WIN82	SPR82	SUM82	AUT82	WIN83	SPR83	SUM83	AUT83
#FCSTS	177	184	174-175	177	180	182	166-174	145-148
EAST......								
TSP--12HR	26	14	6	6	17	12	2	14
24HR	24	17	8	11	21	21	4	19
36HR	22	15	7	11	21	22	3	17
48HR	18	15	5	8	18	17	3	13
BIAS-12HR	61	36	12	8	25	17	3	20
24HR	97	71	22	22	43	44	9	33
36HR	117	83	20	24	62	62	9	32
48HR	130	89	18	27	74	69	10	34
TSNQ-12HR	83	76	72	77	81	76	79	78
24HR	82	74	72	78	83	77	78	79
36HR	81	74	71	79	82	77	78	78
48HR	78	73	71	78	81	75	77	77
%QP	19.8	24.0	30.1	28.3	24.5	30.7	26.0	29.3
WEST......								
TSP--12HR	23	7	4	8	13	7	0	9
24HR	26	16	4	17	23	14	4	20
36HR	21	15	0	13	22	15	9	12
48HR	19	12	0	12	19	15	4	15
BIAS-12HR	80	48	9	15	24	13	1	21
24HR	151	136	14	47	69	46	11	66
36HR	184	195	16	56	78	77	23	67
48HR	229	242	26	55	92	86	25	69
TSNQ-12HR	81	85	94	85	81	86	92	85
24HR	79	83	94	86	84	87	92	87
36HR	76	81	94	86	84	87	92	86
48HR	73	79	94	86	83	87	92	87
%QP	18.4	12.8	6.0	18.1	24.6	16.6	8.6	16.9

.50" Threshold

	WIN82	SPR82	SUM82	AUT82	WIN83	SPR83	SUM83	AUT83
EAST......								
TSP--12HR	18	10	5	2	7	3	1	7
24HR	18	11	6	4	12	13	2	8
36HR	15	9	5	7	12	14	2	9
48HR	13	9	4	5	10	13	2	6
BIAS-12HR	64	36	13	2	10	4	2	10
24HR	103	86	26	9	25	31	6	26
36HR	138	111	22	19	51	48	7	24
48HR	168	126	21	20	60	65	7	27
TSNQ-12HR	56	60	55	49	50	52	58	54
24HR	56	56	54	52	53	54	59	51
36HR	50	52	54	50	49	54	59	53
48HR	49	51	54	51	50	51	60	52
%QP	45.2	40.9	45.5	52.0	53.7	51.0	41.8	48.6
WEST......								
TSP--12HR	18	8	0	1	4	0	0	0
24HR	24	9	0	3	11	1	0	6
36HR	15	10	0	4	10	8	0	3
48HR	16	8	0	6	10	10	0	9
BIAS-12HR	54	33	17	5	6	1	0	0
24HR	112	143	0	21	26	23	4	38
36HR	157	224	17	31	38	57	8	36
48HR	208	257	67	35	65	67	18	45
TSNQ-12HR	60	73	84	59	58	65	67	66
24HR	64	67	87	62	64	66	68	65
36HR	57	66	86	63	63	67	67	70
48HR	56	67	81	63	59	68	68	68
%QP	50.0	31.8	14.0	42.0	46.4	36.2	32.9	36.8

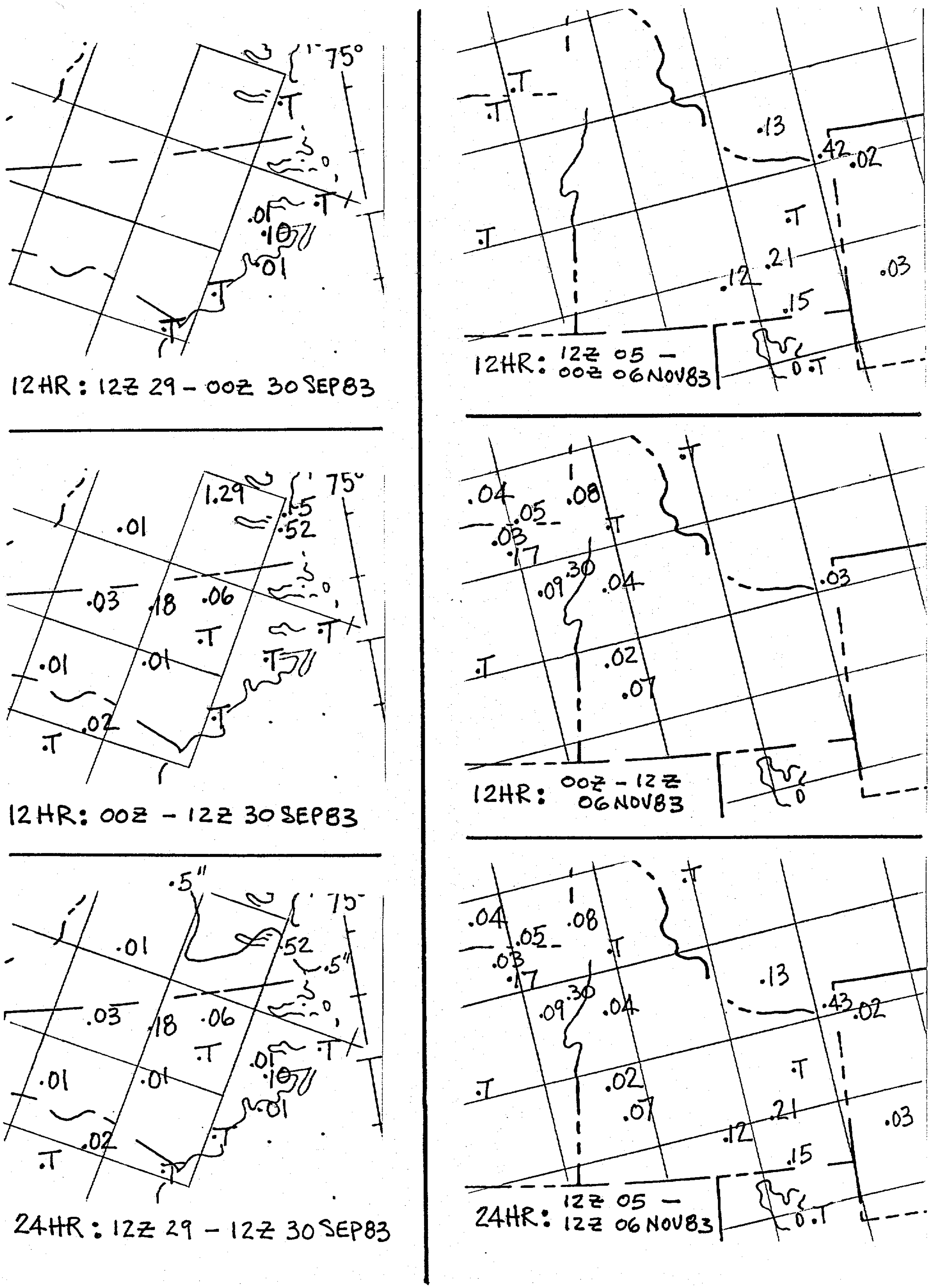


PRECIPITATION VERIFICATION NETWORK: GRID POINT SYSTEM

LFM Forecast Grid Array (321 points)
OBSVD Same as LFM
SMG 89 Pts: ● (Forecast Grid Point)
○ (Interp. to OBSVD Location)
□ (Interp. to Station Location)

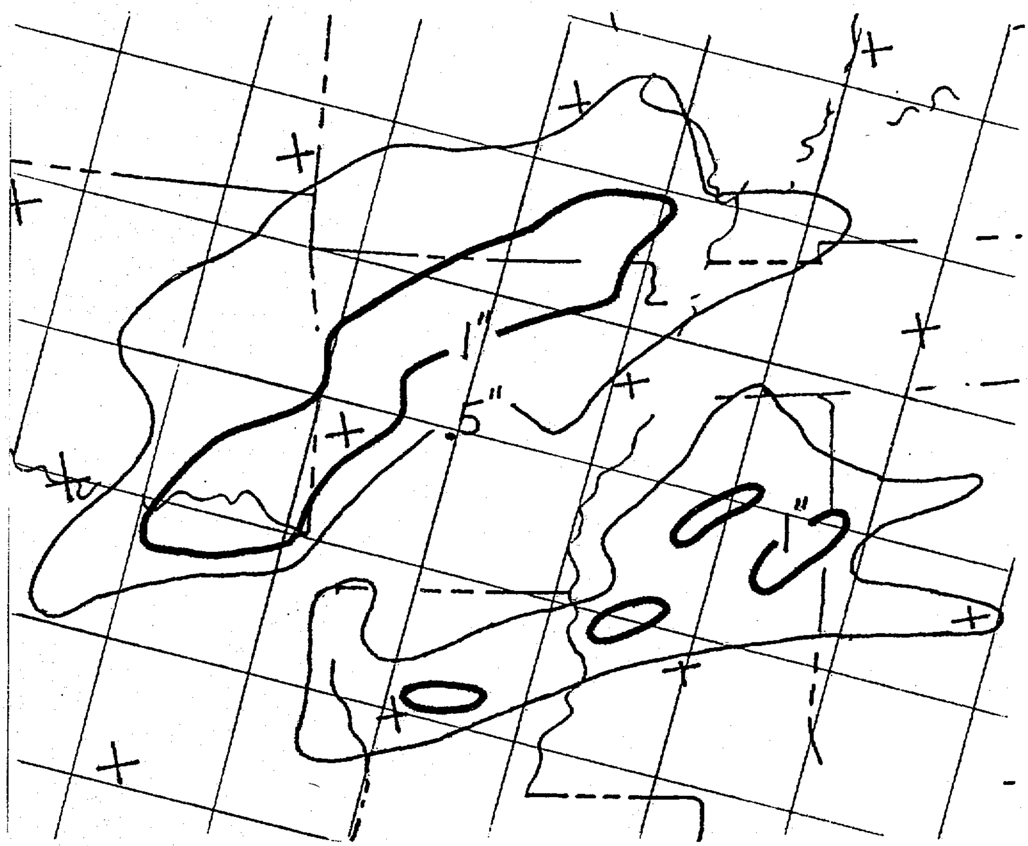
FIGURE I

OBSERVED PRECIPITATION FIGURE II



24 HOUR OBSERVED PRECIPITATION
.5" (Thin), Whole Inch (Heavy)

FIGURE III



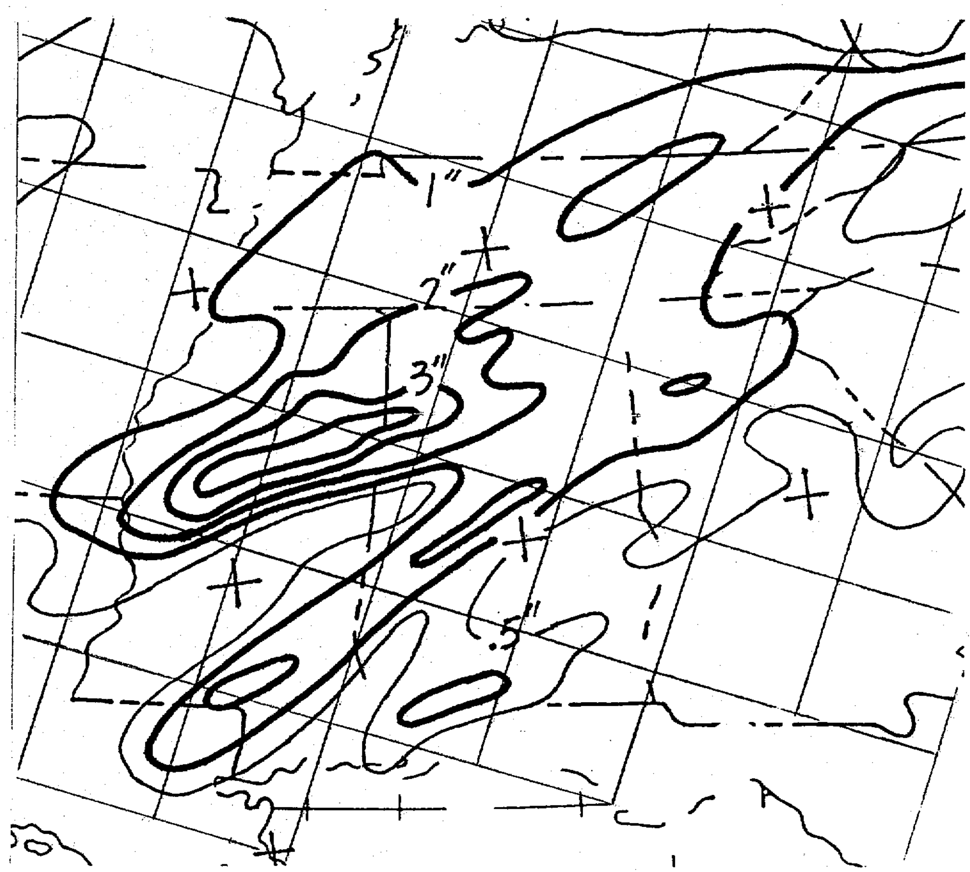
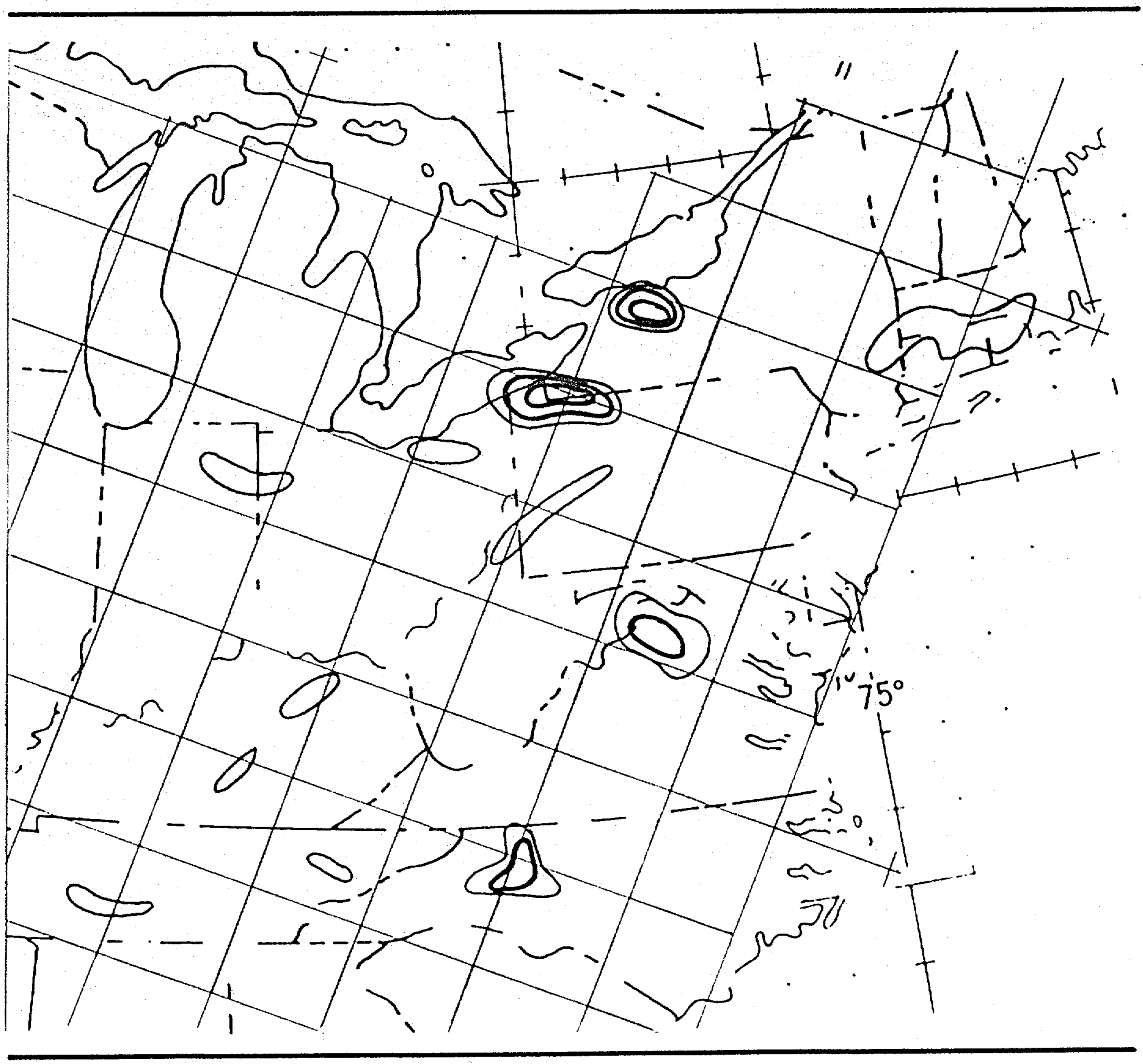


FIGURE IV



24 HOUR OBSERVED PRECIPITATION

.5" (THIN)

WHOLE INCH (HEAVY)

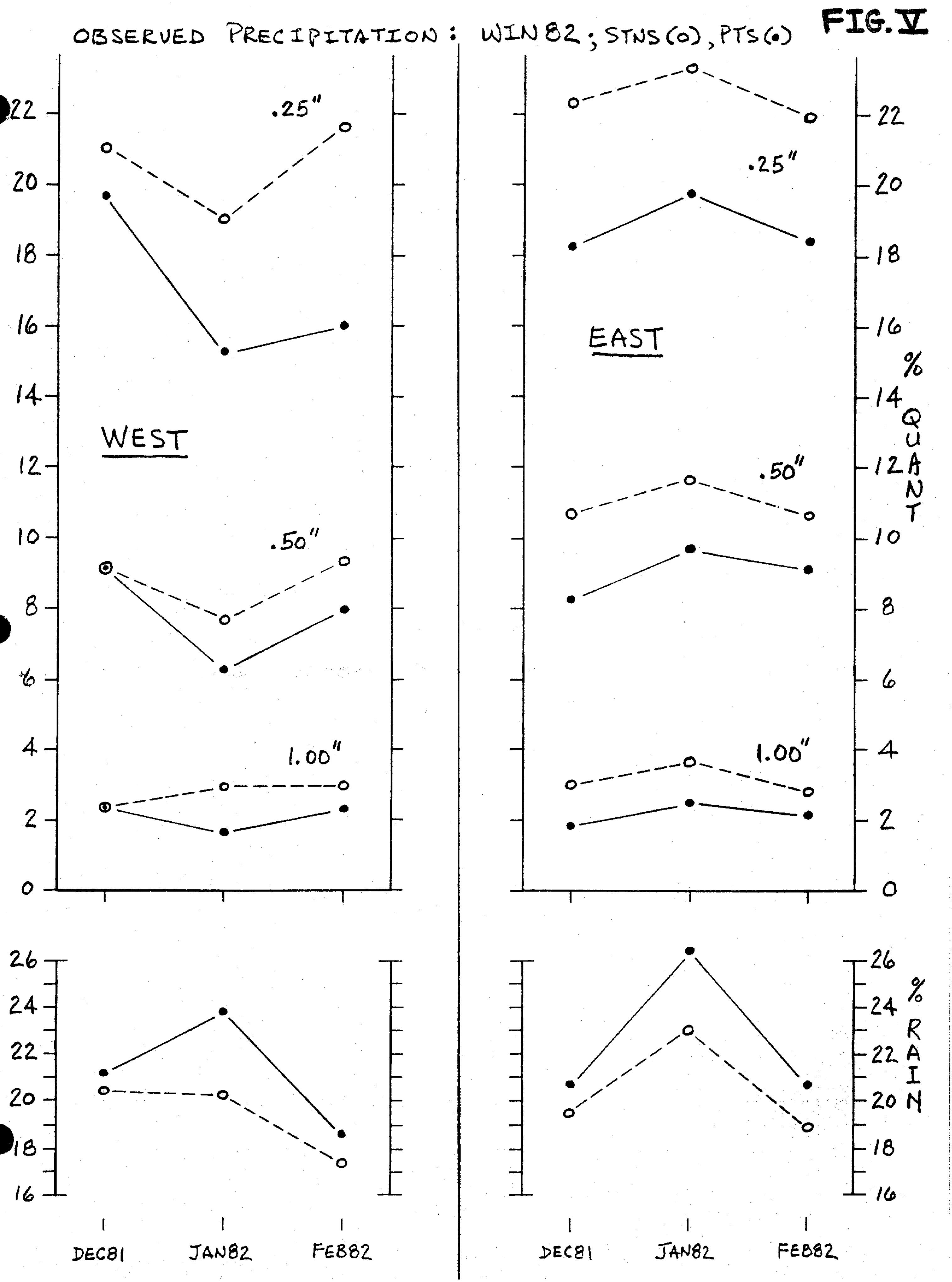


FIG. V
OBSERVED PRECIPITATION: WIN82; STNS(o), PTS(•)
WEST
EAST
.25"
.50"
1.00"
% QUANT
% RAIN
DEC81
JAN82
FEB82
0
2
4
6
8
10
12
14
16
18
20
22
24
26

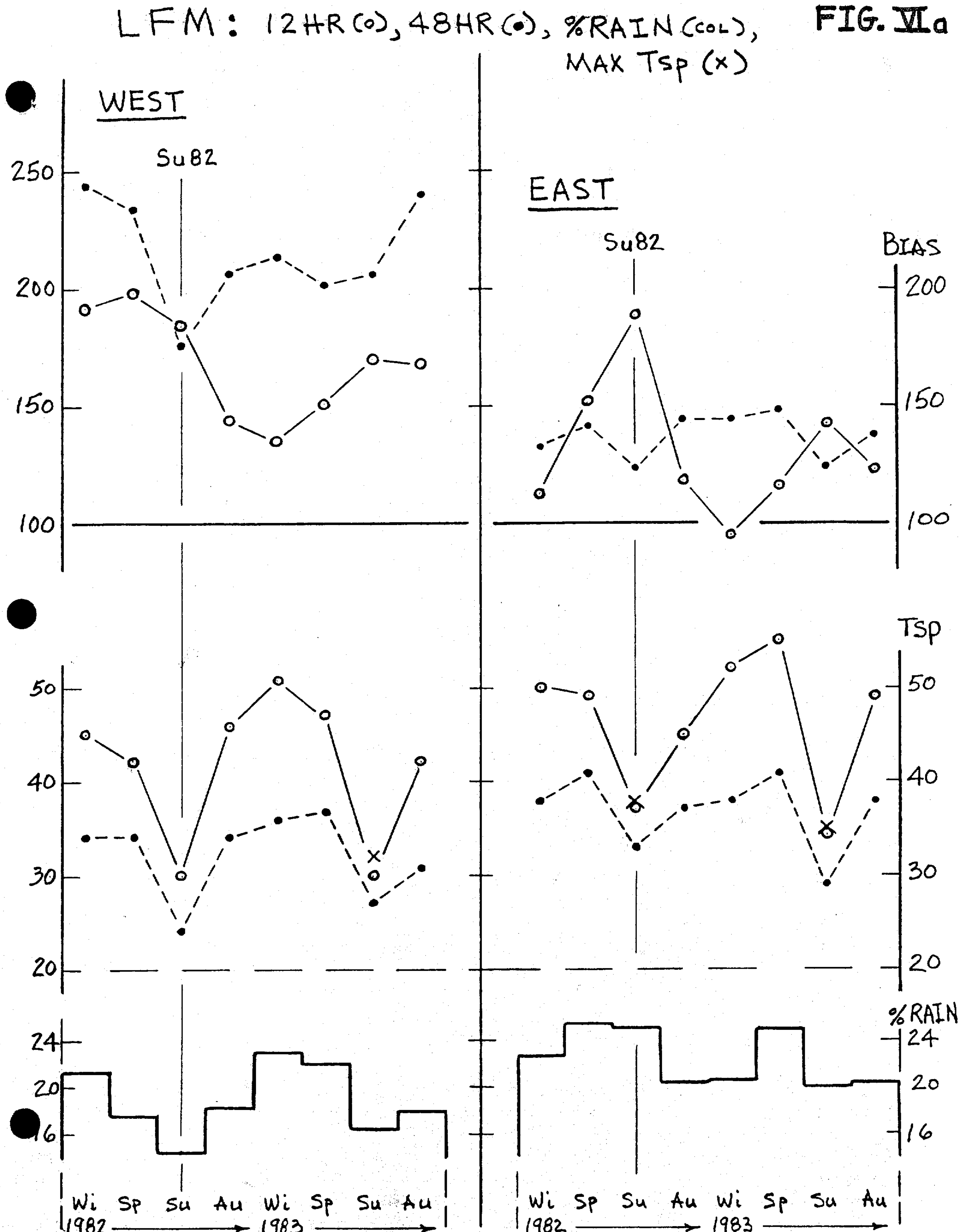

LFM: 12HR (o), 48HR (•), %RAIN (COL), MAX Tsp (x)
FIG. VIa
WEST
EAST
Su82
Su82
BIAS
250
200
150
100
200
150
100
Tsp
50
40
30
20
50
40
30
20
%RAIN
24
20
16
24
20
16
Wi Sp Su Au Wi Sp Su Au
1982 → 1983 →
Wi Sp Su Au Wi Sp Su Au
1982 → 1983 →

FIG. VIb

SMG : 12 HR (o), 48HR(•), %RAIN (COL), MAX Tsp (x)